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(71) Applicant: **UNION ESPANOLA DE
EXPLOSIVOS S.A.**
Claudio Coello 124
E-28006 Madrid(ES)

(72) Inventor: **Fernandez Cabezas, Carlos**
Soto de las Rozas 115
Las Rozas (Madrid)(ES)
Inventor: **Ibarraza Moreno, José**
Avda. de Lobato 58
Logrono (Rioja)(ES)

(74) Representative: **García Cabrerizo, Francisco**
OFICINA GARCIA CABRERIZO S.L. Vitrubio 23
E-28006 Madrid(ES)

(54) **Electronic detonator-exploder system for high-reliable stepped detonation.**

(57) This invention relates to an exploder detonator unit capable of electronically sequencing a blast. The exploder - - equipment of the unit which is described is intended to -direct the explosion sequence of several electronically -delayed detonators connected in parallel or series via a bifilar line that thus permits a simpler connection, and leads to handling at low risk voltage and current; in - - addition allowing simultaneous connection of several hundred detonators at the same time. The process, as far as the final detonation, is implemented in stages which involve specific actions by the user and include safety and control codes in each of them. Provision is made in the present invention that, if the connection control system gives a positive response, a change in the safety voltage to that of detonation is produced, a signal is activated and the final stage is proceeded to, whether of detonation or of disarming. In the present invention, the detonator element has a protection against any undesired electrical phenomenon, using switches that short-circuit and isolate the resistive element or igniter. In addition to all this, both the exploder element as well as the detonator element - - possess, in the present invention, a system for detecting the correct functioning as well as the connection of each detonator situated in the blast. These detonators are - - response-time programmable, a programming which can be -effected from the exploder itself.

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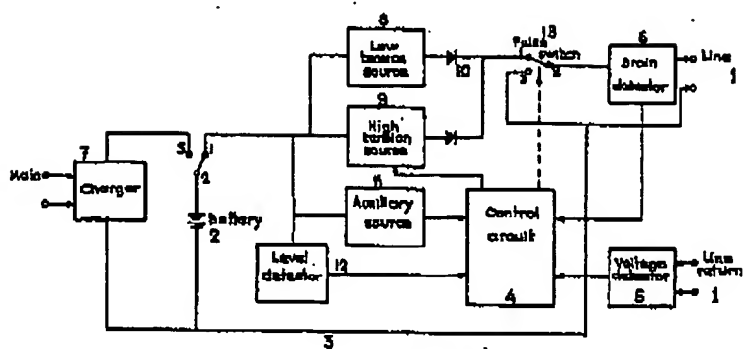


Fig. 1

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ELECTRONIC EXPLODER DETONATOR SYSTEM FOR HIGH RELIABILITY PHASED DETONATIONBackground

The most significant benefits and advantages of the system which is the subject of the present invention as against conventional blasting systems are:

- 5 - Restricted exploder handling, by means of a safety access key.
- Possibility of fault detection in any one of the detonators before activating firing.
- The system incorporates a test procedure which guarantees the detection of the possible failure of a detonator because of a deficiency in the connection.
- Possibility of temporizing the activation of several detonators.
- 10 - Use of a safety key which prevents the detonator being activated by any direct or alternating current source, if it has not previously received the coded electronic key.
- The system uses a power back up element of small dimensions which makes it possible to achieve a very small size for the detonator circuit.

Exploder detonator systems of electronic type are described in the state of the art.

- 15 In particular, in Spanish Patent No. 538,830 and in US Patent 4,588,437, systems of this type are described. In neither of them does there appear included a key-code guidance control system for the detonators, which allow [sic] their complete identification in the line of firing, which represents one of the main elements of the present invention. Likewise, neither does there appear envisaged in the patents mentioned any additional safety system in the handling, using relays that would isolate the relative
- 20 element, which is now envisaged in the present invention.

Description of the invention

- 25 The two basic parts of the exploder equipment Fig. 1 are: an analog voltage and current generation and control part, governed by another digital control part, implemented by a microprocessor with built-in memory, which directs the process and services the keyboard and indicators. This second control part also generates the commands which are transmitted, by means of modulation of the line voltage, to the detonators.

- 30 For greatest ease of interaction in the explosion sequence, the control data are introduced via a numeric keyboard and specific test keys, arming and detonation, according to the particular information which continuously appears on the alphanumeric display designed for said purpose.

- As a first stage, once the exploder is initialized, it requests the introduction through the numeric keyboard of an access code of several fixed and user-programmable digits, allowing access to the detonation process if said code is correctly introduced. Acceptance of the keys, in this case and in all those
- 35 mentioned below, is effected using a filtering procedure which eliminates possible erroneous interpretations of commands.

- Once the access control stage is passed, the detonator line test stage is proceeded to. In this, the exploder requests actuation of the test key, from which moment it awaits a response from the line continuity and connection control system, with the aim of maximizing the reliability of detonation of the complete
- 40 system. Line continuity can be ensured using a loop therewith, connecting it up to a safety voltage and checking the voltage in the return end Fig. 1 (5). This safety voltage is unable to set off the final ignition element, even in the event of all the existing means of protection failing, and is modified only in the final stage of the procedure. Likewise, the correct connection and functioning of the detonators involved in the blast is ensured by transmitting an encrypted code which, on being accepted by the detonators, gives rise
- 45 to the momentary disconnection thereof from the line, involving a zero current consumption in the latter. Using a current sensor Fig. 1 (8) said datum is checked which, together with the checking datum of the stated voltage, gives rise to the test response.

- The possible identification, by means of codified response, of all the detonators and recognition thereof on the part of the exploder control unit is also envisaged, the transmitted code, here as elsewhere, is sent
- 50 encrypted, with added units of information for the reception control, in backup mode and using a PDM transmission, whether carried by FSK modulation or not. Taking into account that the information is transmitted along the same line that carries the supply voltage, this modulation provides good immunity to electrical noise at the same time as, choosing a low duty ratio, giving rise to a minimum energy storage for the maintenance of the supply to the control unit of the detonator. Being a transmission with built in synchronism in the data themselves, for greater security, synchronization is effected in each datum sent by

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incorporating a fixed synchronizing datum in front thereof.

If the test gives a positive result, as has already been mentioned, the detonator arming stage is proceeded to. In this, the exploder requests the introduction of the basic delay unit via the numeric keyboard, and the depression of the arming key. The basic delay unit is a number between 5 and 99, which will be the period, in milliseconds, of the time adjustment pulses which will be sent by the exploder to the detonators: said time multiplied by the particular number for each detonator (between 0 and 2^n , with n ranging between 4 and 8) will be the definitive delay time thereof. It should be noted that the precision of said time depends on that of the master oscillator (included in the control circuit) existing in the exploder, and not on that of the low precision oscillators of the detonators (included in the control circuit of the latter).

Once a valid delay unit is introduced, its value remains on display and depression of the arming key is enabled. Once the depression of said key is accepted, a long encrypted key code is sent, which, if recognized by the detonators, positions them in temporal adjustment mode of their particular delay time.

At that moment, the exploder transmits 2^n pulses of period equal to that of the basic delay unit in order to effect the stated temporal adjustment. Once said pulses are transmitted, with or without the prior transmission of an encrypted, arming check code, the detonators can execute a momentary disconnection action. If the connection control system gives a negative response, indicating that the key code has not been recognized or that the time units contained abnormal variations, the whole arming procedure is automatically repeated. If this second procedure also gives a negative result, the exploder sends an encrypted and modulated detonator disarming code, reinitializing the procedure at the test stage.

If the connection control system gives a positive response, the change from safety voltage to that of detonation is produced, a signal is activated, and the final stage of disarming or detonation is proceeded to. In this, the exploder requests the actuation of the disarming key or of the detonation key. If the disarming key is depressed, an encrypted and modulated backup code is sent which reinitializes the procedure, the exploder subsequently remaining positioned in the stage previous to the test and the total system in a position to be shut down or reactivated. By contrast, if the detonation key is depressed, an encrypted and modulated backup code is transmitted, initializing the detonator temporization procedure. After a few moments, the exploder reinitializes and remains prepared for a new procedure.

Regarding the energy source, the exploder is supplied by a rechargeable battery Fig. 1 (2), provided with a charger Fig. 1 (7) which may be connected to the mains power supply. The two different levels of supply voltage already mentioned are obtained from this battery, by means of linear or switched sources of supply Fig. 1 (8) and (9), which converge in a single common output through a gate consisting of power diodes Fig. 1 (10), which always allows the highest available voltage to pass.

The supply source of lowest voltage represents the safety level for the detonators and is permanently connected to the output. By contrast, that of highest voltage, which represents the level sufficient for detonation, delivers output under the control of the control unit. Therefore, as long as the order for the detonation voltage supply does not appear, the safety voltage appears in the output, being replaced by that of detonation when the control unit requests it, according to the procedure already described. Both sources allow for the connection of more than 500 detonators.

A third linear supply source Fig. 1 (11) provides the voltage necessary for the operation of the control unit.

On the other hand, an alarm circuit Fig. 1 (12) supplies an indication to the control unit when the battery voltage falls below a certain minimum level. At that moment the exploder fixes an indication about the situation on the display and inhibits its operation, thus preventing the attempt to effect a detonation manoeuvre without the availability of the necessary energy.

After the stated gate is placed a two-position electronic switch Fig. 1 (13) capable of disconnecting the output of the exploder, which at rest remains connected, and connecting it to earth (opposite pole) according to the commands received from the control circuit, with the aim of transmitting near zero signal pulses to the line. The connection to earth during the pulses, rather than simple opening, allows improvement of the quality thereof, avoiding the picking up of electrical noise. This switch is operative whatever the output voltage.

Regarding the detonator Fig. 2 of the unit described, it is designed to be adaptable to the control sequence which is described for the exploder, by means of its parallel excitation by a constant voltage source. Its physical implementation is in the form of a hybrid circuit and it is positioned in a housing with similar external appearance to that of conventional detonation elements. It contains two distinct parts: one analog part for line handling and energy control, governed by another digital control part, analyzing and executing the commands received.

With the aim of achieving the small size required for the whole detonator circuit, surface-mounting elements and a large-scale integration circuitry are used, without encapsulation, and implemented with low

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supply voltage technology and very low working current which allows the use of an energy backup element of small dimensions.

A rectifier element Fig. 2 (1) is placed after the voltage and signal input from the line-connecting wires, which makes it possible to ignore the necessary polarity of the electronic circuit at the moment of connection of the detonator to the line.

A general pass switch Fig. 2 (2) is placed immediately afterwards, which is closed in the rest state and whose actuation, briefly opening the complete circuit, can be effected by the control circuit using the relevant command. In this way the exploder can acknowledge the correct operation of the system, as has been described.

Two pass channels are connected immediately after this with the aim of separating the supply from the signals which, in the form of near zero pulses, are superposed on the feed.

The feed current circulates through a diode Fig. 2 (3) towards a new fork formed by a stabilizer Fig. 2 (5) in series with a reference diode, in order to obtain a fixed voltage, and a pass gate Fig. 2 (4) towards the accumulator circuit of the detonation energy and of the controller circuit thereof. This second channel is initially closed; this is not the case with the first, which supplies the detonator control circuit, as well as the pulse separator circuit Fig. 2 (6).

As it may be the case that the supply circuit is provided with an energy backup Fig. 2 (7) in order that this be maintained during the presence of the signal pulses, the abovementioned diode is necessary so that this energy backup does not nullify said pulses. Moreover [sic], it should be sufficient to maintain adequate supply to the whole electronic circuit during the maximum foreseen delay time in a detonator, even though its connection to the exploder has been interrupted by the detonation of any other detonator of a multiple chain.

The detector circuit Fig. 2 (5) for the signals in the form of near zero pulses in the supply voltage converts these into positive pulses of magnitude equal to the voltage fixed by the rectifier in series previously described, whatever may be the line supply voltage.

The second supply channel previously mentioned, which initially remained inactive, opens the line supply route towards a new energy backup Fig. 2 (8) as soon as the control circuit gives the relevant command for this. This energy backup is necessary in order to effect detonation by means of setting-off the igniter. The switch is of the no-return type Fig. 2 (9), with the aim of ensuring the complete draining of the energy backup on the igniter.

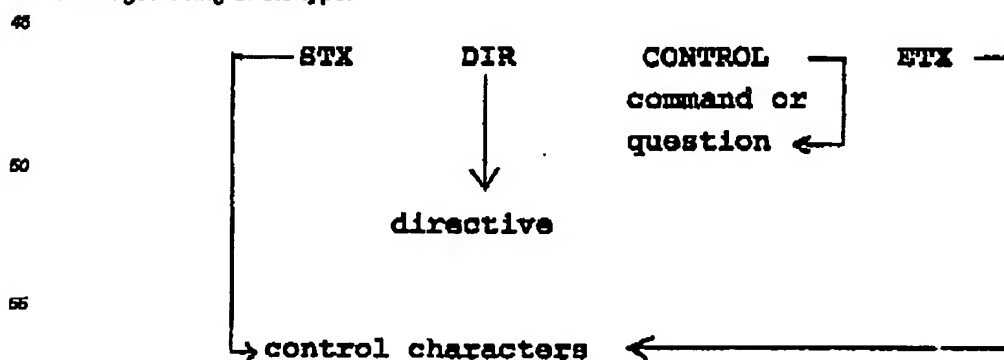
As regards the detonator control circuit, it can be implemented with a USIC (User Specific Integrated Circuit) circuit, or a microcontroller with built-in memory or an ASIC (Application [sic] Specific Integrated circuit) circuit. Said circuit effects the reception of data, analyzing the reception of line synchronizations and continuously verifying the validity of each basic unit of information, as well as of the key code and of the commands received.

Moreover, each detonator possesses a unique direction code which identifies it unequivocally from the remainder of the detonators connected in a single blast.

The "direction" of the detonator is based on the recognition of a binary code by the microprocessor program. This code can be included in a microprocessor memory location.

The exploder emits two types of messages: those that are intended for the totality of the detonators (e.g. "fire") and those that are directed at a specific detonator (e.g. those in search of connected detonators).

These latter are headed by the code for the direction of the detonator to which it is directed, the messages being of the type:



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These messages are physically transmitted by the line shared by the detonators. When these detect the existence of a message, they place themselves in listening mode in order to "read" the directive; if it coincides with their own, they respond to the specific command in the message, and if it does not coincide, they ignore it.

5 In the whole detonator activation procedure, the guidance factor intervenes essentially at the beginning, when the exploder initiates the "search" for connected detonators in a correct operating state.

The exploder shows, in succession, the detonators that it continues to "find" connected to the line. At the end, the number of detonators "found" should coincide with the number of detonators that were manually introduced into the exploder.

10 The following is given by way of illustration and without any limitation being implied.

Example

Supposing it were necessary to effect the blasting of several detonators (5 units) of the same interval
15 no., for example no. 17, and with different directives according to the system which is the subject of the invention.

XX YY,

20 where XX represents the number of time intervals to form the total temporization of the firing.

YY serves to distinguish between two detonators with the same interval number.

In the event that they are properly connected, the exploder would read and would find the following pairs of numbers

25 1701
 1702
 1703 supposing that the rank of the chosen directives
30 1704 were from 1 to 5
 1705

Equally, several detonators of distinct time interval may be found in the exploder sweep. Let there be,
35 for example, 5 detonators of interval no. 10, 11, 12, 13, 14. The single directive of these detonators is, for example, no. 13. The exploder would read

40 1013
 1113
 1213
 1313
 1413

45 Once the test operation is effected and once the key code is identified, the operation of adjustment of the individual delay time by means of the integration of pulses from the local low precision oscillator during m of the 2ⁿ high precision pulses received from the exploder, m being a number predefined in the hybrid circuit by means of the implementation of junctions or breaks in n lines, laid out for this purpose and detected by the control unit[etc] It also implements, once the detonation command is accepted, the
50 temporization procedure which ends with the detonation of the element, as has been described.

The detonators addressed by the invention have means of protection against undesired electrical discharges.

These means of protection consist in the use of relays Fig. 2 (10), in such a way that, normally, the resistive element Fig. 2 (11) remains short-circuited and possibly connected Fig. 2 (12) to the metal casting
55 of the detonator. In this way the resistive element is protected from any electrical disturbance that might provoke a chance firing, since these parasitic voltages find a path of lesser impedance.

This protection disappears at detonator arming, by means of activation of the relay, leaving the resistive element ready for firing.

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Claims

1. A combined electronic exploder detonator system, which consists of an analog generation and supply current control part, and another digital control circuit part, consisting of a microprocessor, with built-in memory which directs the procedure.
2. Operating procedure of the system of Claim 1, which is implemented according to the following stages:
- 1a) Introduction of the access code to the system.
 - 2a) Test of connection of the line of detonators.
 - 3a) Introduction of the basic delay unit.
 - 4a) Arming or activation of the detonators
 - 5a) Detonation if it proceeds and the response of the test is positive, or disarming if the connection control system detects a fault or a bad status in any of the detonators in the line.
3. System and operating procedure according to Claims 1 and 2, in which the supply currents exhibit two voltage levels, such that the lower level is unable to initiate the igniter or resistive element, this being considered as the safety voltage.
4. System and operating procedure according to Claims 1, 2 and 3, in which the trial stage or test consists of a sweep of all the codified directives in each detonator, which are predefined and joined via the microprocessor, unequivocally, to the delay time of each detonator.
5. System and operating procedure according to Claims 1, 2, 3 and 4, in which the maximum safety of operation and handling is achieved, through the installation of suitably situated relays, so as to isolate the igniter or resistive element of the detonator until the moment immediately prior to firing.

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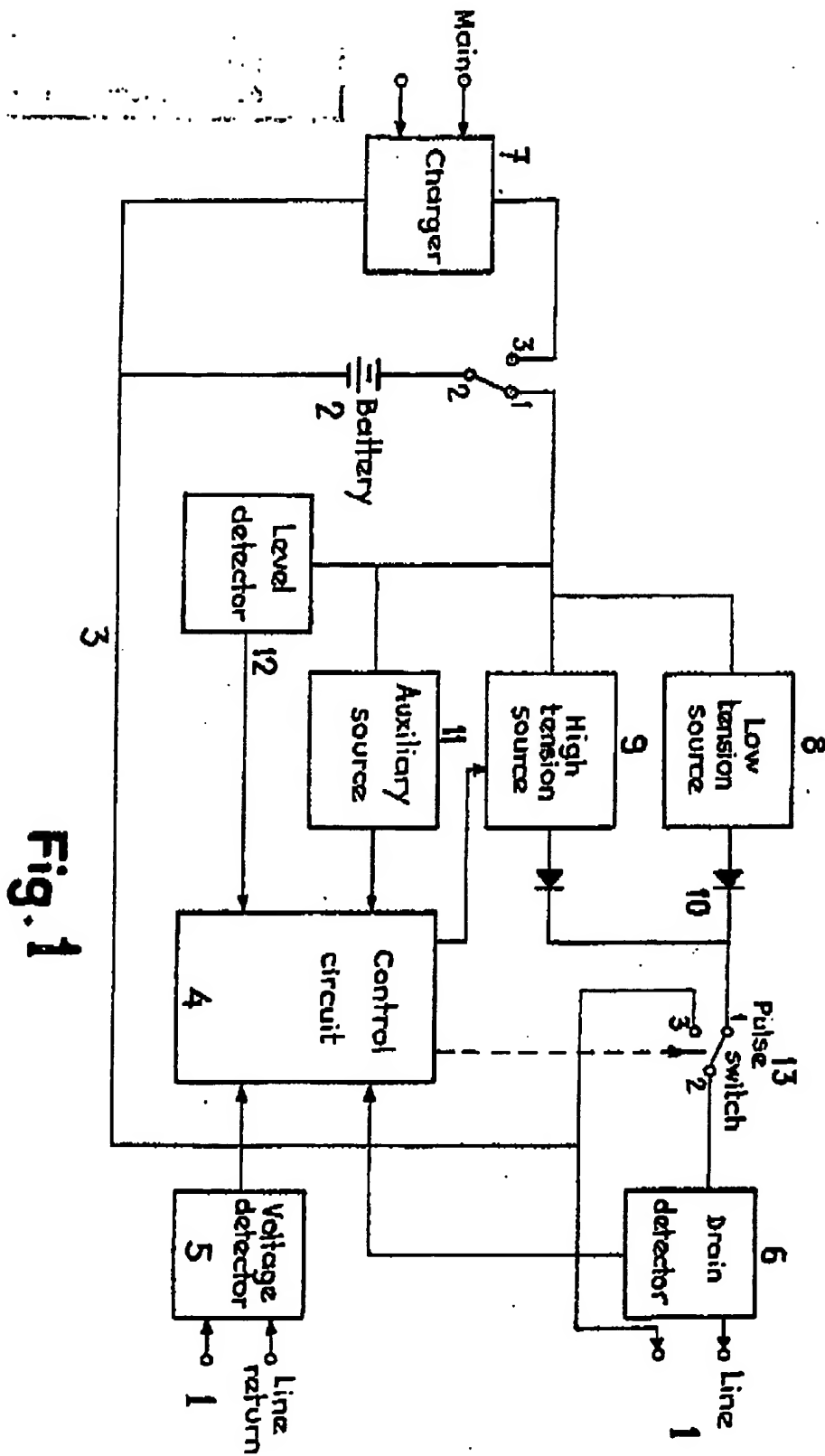


Fig. 1

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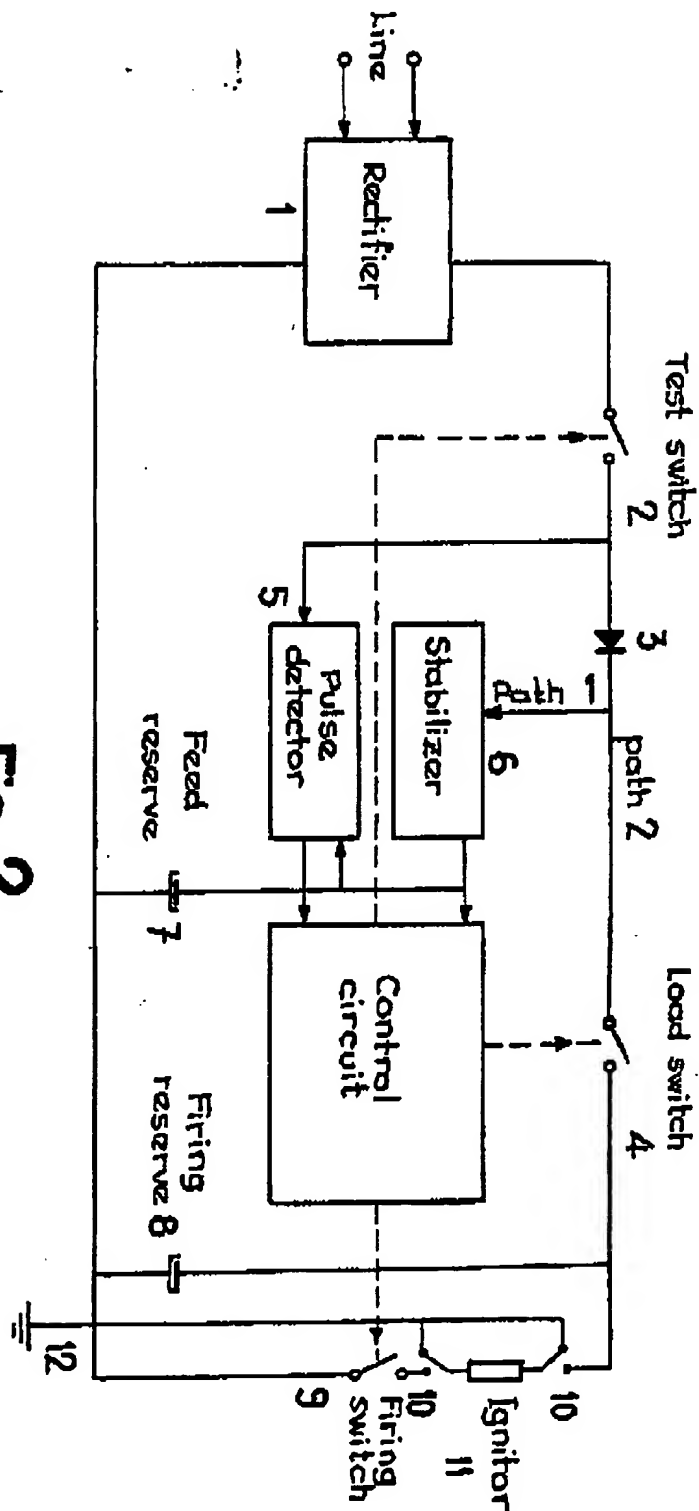


Fig. 2